Surface plasmons are collective electron oscillations, which are propagating at a metal-dielectric interface. They are generated at optical frequencies and show confinement into areas much smaller than the wavelength of light, which causes a strong increase of the electric field intensities. This enhancement is especially pronounced in case of nanometer sized metal particles. Various applications, ranging from novel light sources, photovoltaics to sensor devices take advantage of the extraordinary optical properties of such metallic nanoparticles.

Electron energy loss spectroscopy (EELS) in combination with scanning transmission electron microscopy (STEM) allows probing the evanescent fields of such localized surface plasmons with nanometer resolution [1]. Alternatively energy filtered transmission electron microscopy (EFTEM) can be used to map localized surface plasmons as it was shown in previous works [2, 3], providing similar information as with STEM-EELS. Because of the capability of the transmission electron microscope used in this study (FEI Tecnai F20) to reach better energy resolution in STEM-EELS than in EFTEM mode, we used the scanning mode to optimize energy resolution down to 0.12 eV. A monochromated 200 keV electron beam was used to excite surface plasmons on different nanostructures, while the electron energy-loss was measured in order to get spatially resolved spectral information from the near-infrared, the visible and the UV range. Nanostructures of different geometries were designed using electron beam lithography (EBL), a technique suitable of creating thousands of nanostructures in just a few minutes.

The EBL processing was realized on a 15 nm thin silicon nitride membrane. This material exhibit a band gap of about 8 eV, leading to no extra EEL signal in the optical range. 30 nm silver nanostructures were prepared and an additional 18 nm silicon oxide film was evaporated in order to reduce degeneration of the silver surface. EEL measurements were generated on a FEI Tecnai F20, equipped with a monochromated field emission gun and a high resolution Gatan Image Filter.

Starting with single nanodisks, where we found a new type of plasmonic excitation, the so called breathing mode [4], we continue our study by morphing the shape of a disk to a triangle ("Figure 1"). Only with the help of theoretical calculations, which are in good agreement with the experiment, we are able to understand and interpret our findings [5]. We show which localized surface plasmons found in a single nanotriangle can be linked to plasmonic eigenmodes in a nanodisk, and how other LSPs differ in these 2 basic geometries. We will discuss the importance of plasmon hybridization in the context of mixing fundamental modes to a hybridised excitation.

In the second part of this work we deal with the question how symmetry breaking of a nanodisk by creating designed defects ("Figure 2") affects the plasmonic behaviour of such nanodisks. A systematic change of designed defects in a nanodisk is realized by using electron beam lithography and a comparison of a comprehensive EEL-study is presented.

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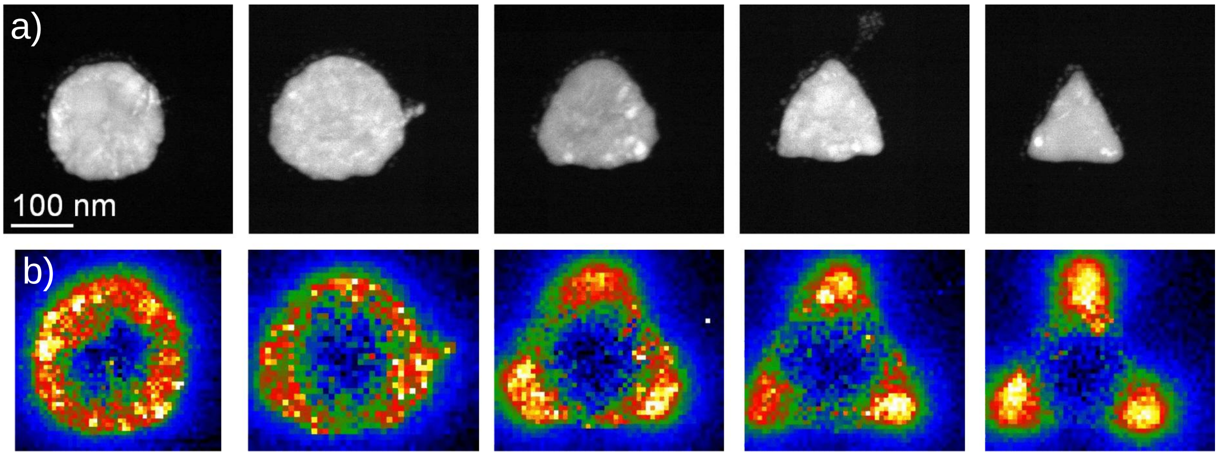

Figure 1. Morphing a silver nanodisk to a nanotriangle. a).High-Angle Annular Dark-Field (HAADF) images from 30 nm thick silver nanoparticles, ranging from nanodisk (left) to nanotriangle (right). Particles are prepared with electron beam lithography (EBL) on a 15 nm thin Si_3N_4 membrane. b) Corresponding EEL-maps from particles shown in a), where the electron energy-loss intensity of the plasmonic dipole excitation is shown as function of the lateral position.

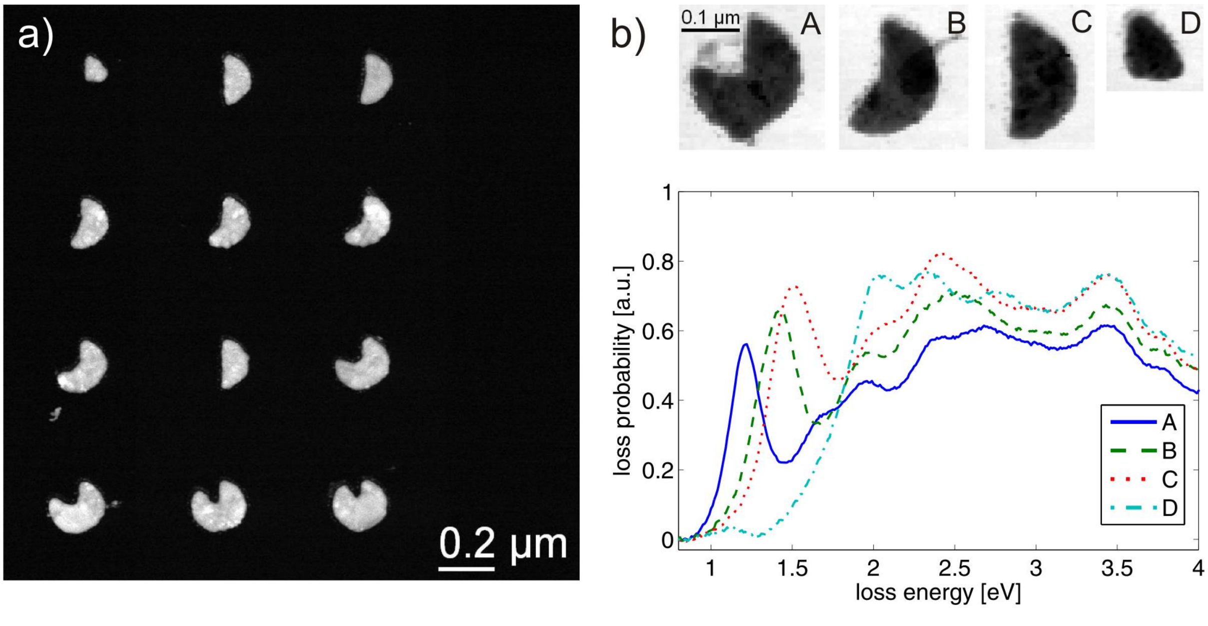

Figure 2. Nanodisks with designed defects. a) HAADF image of silver nanostructures of 30 nm thickness on a 15 nm thin Si_3N_4 membrane, coated with a 18 nm SiO_2 layer for better stability of the silver film. Particles were prepared using EBL. b) Spectrum images A, B, C and D of selected particles, prepared under same condition as particles in a) (top). Extracted EEL spectra A, B, C and D from spectrum images shown above (bottom).